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The Hiorth Electric Steel Furnace [with discussion]

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THE HIORTH ELECTRIC STEEL FURNACE.

By Joseph W. Richards.

This is an improved form of induction electric furnace, patented in Norway by Engineer Albert Hiorth (No. 19,955, May 14, 1909) and in the United States by C. W. Söderberg (No. 954,827, April 12, 1910). Mr. Hiorth has invented the main features of the furnace, while Engineer Söderberg has patented some details and has designed the furnace now in practical operation.

Some of the information following is taken from a lecture given by Mr. Hiorth at the Polytechnic Institution, Christiana, April 19, 1910, and part is from the personal observations of the writer at the works of the Jossingfjord Manufacturing Company, at Jossingfjord, Sogndal in Dalene, on the southwest coast of Norway, on September 5, 1910.

The natural conditions are particularly favorable in Norway for the development of electrometallurgical industries, since electrical power can be had in large quantities on ice-free deep-water harbors at $5.00 to $7.50 per horse-power year, with cheap ocean freights to and from all parts of the world.

In 1905, Mr. Hiorth and his father, Mr. F. Hiorth, took active steps to have a government commission appointed in Norway to inquire into the electrical production of iron and steel. The Polytechnic Institution of Christiana co-operated actively with them, with the result that a "Metallurgical Committee" was appointed by the government on May 24, 1907. This commission made a report in 1909 (Christiana, printed by H. Aschehoug and Co.), in which Prof. J. H. L. Vogt gave a short account of the Norwegian stock of iron ores, and the whole committee (C. A. Thorne, P. Farup and Prof. Vogt) reported upon the status of the electrometallurgy of iron and steel and upon the prospects of its future development in Norway.

Shortly after, the Messrs. Hiorth made inquiries of the holders of patented electric furnaces as to license rights for Norway. The royalties demanded were not moderate, nor yet excessive, but the difficulty arose that the licensors required the Norwegian works to limit themselves to a low *maximum* output, as they did not wish the Norwegian product to compete with their own product in other countries; some even required that the Norwegian product should not be sold outside of Norway, thus intending to limit the Norwegian works to the small requirements of Norway and to prevent it entering into competition in the

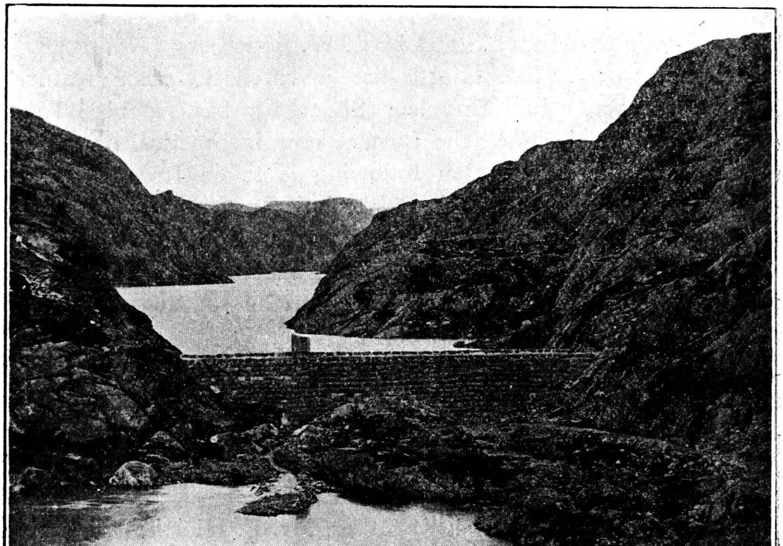

Fig. 1. The Storage Reservoir.

world's steel markets. Under such conditions, an arrangement with foreign inventors was practically impossible, since Norwegian capitalists could not see the way clear to a proper development of the new industry.

Mr. Hiorth then constructed and patented, himself, a special type of electric furnace and offered it to Norwegian investors. As a consequence, the Jossingfjord Manufacturing Co. (Mr. Borger, president) became interested, developed a water-power sufficient for running a 10-ton furnace, and installed a 5-ton furnace, which was just put into operation early in 1910. In many places on the west coast of Norway, electric current can be developed from water-power at a total installation cost of \$25 to \$30 per horse-power and at a total working cost of

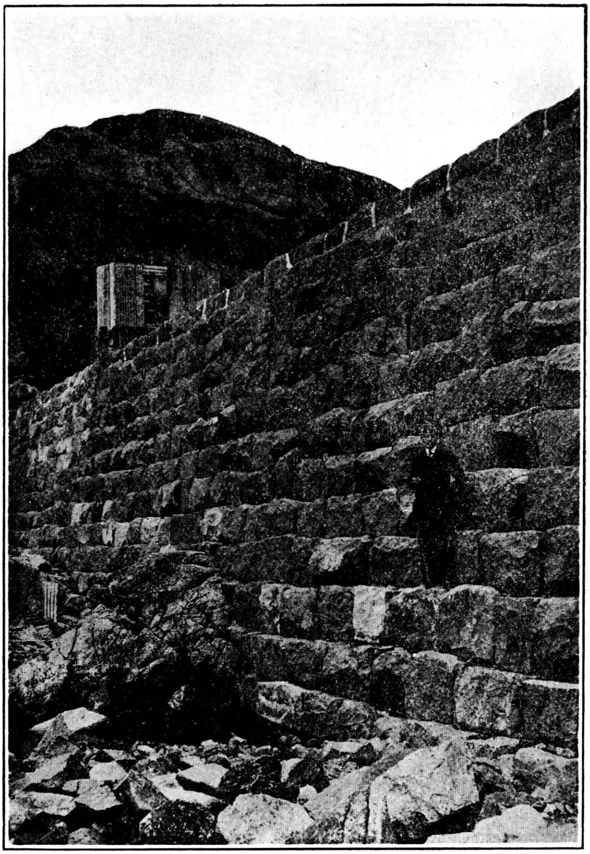

Fig. 2. The Dam.

\$4.25 per horse-power year. The plant at Jossingfjord falls within these conditions.

Figures 1 to 6 show the general details of the plant and its location. Mr. Jacob P. Nissen was engineer in charge of the power plant. The storage reservoir is 400 feet above the power

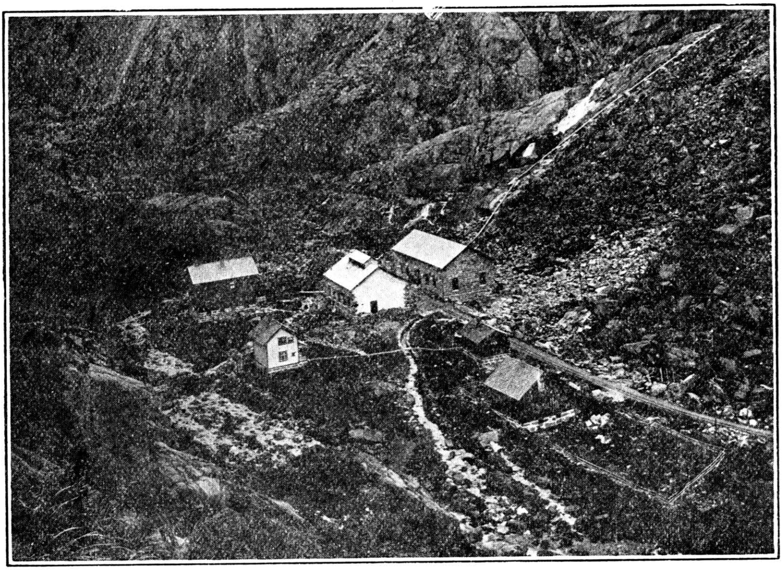

Fig. 3. The Plant, looking up-stream.

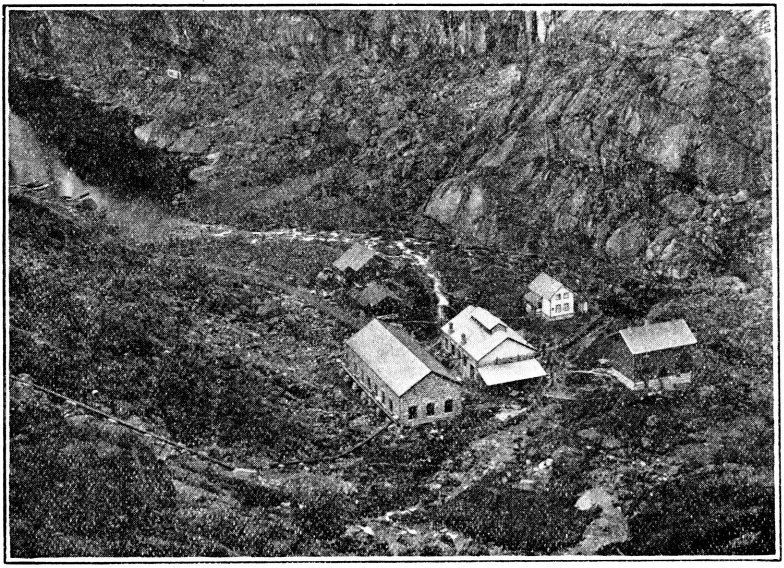

Fig. 4. The Plant, looking down-stream, showing landing place and fishermen's houses under the cliffs.

station; only rocky country was inundated by it. There is a minimum of 1,000 horse-power available. The 18-inch iron conduit brings the water to a Pelton wheel directly coupled to the generator, as shown. The latter delivers 400 to 500 kw., at 250

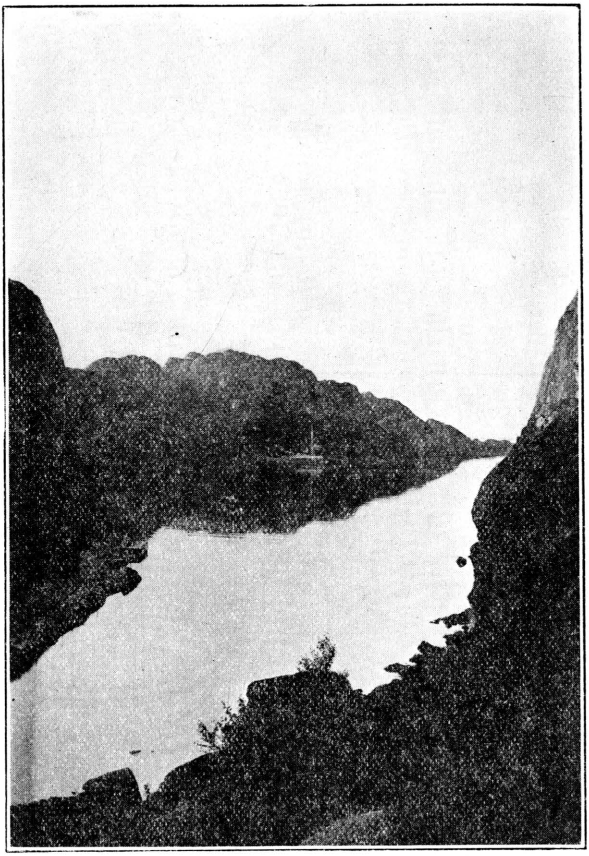

Fig 5. The Wharf and Tramway, looking Seaward.

volts, 12½ cycles. The copper cables to the furnace house are about 50 meters in length, and have a cross-section of 1,000 sq. mm. A tramway connects the works with a deep-water pier, distant about 200 meters.

The Hiorth electric furnace at present in operation at the

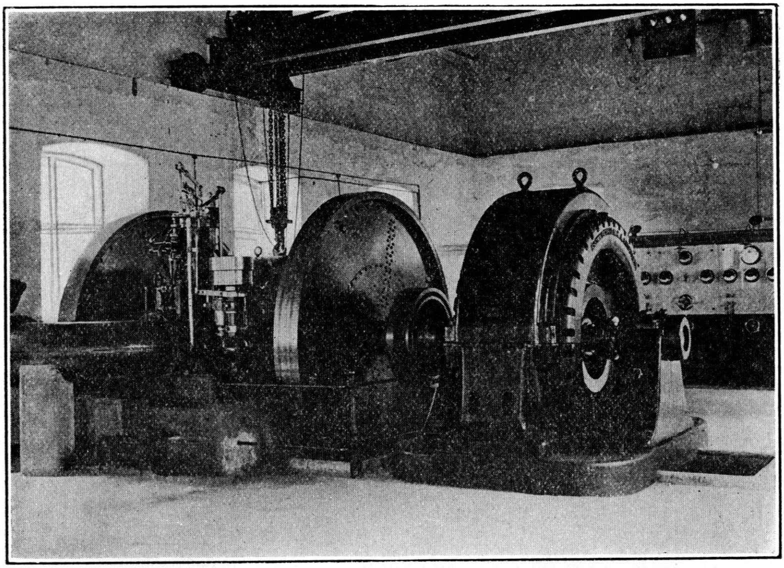

Fig. 6. The Pelton Wheel and Dynamo.

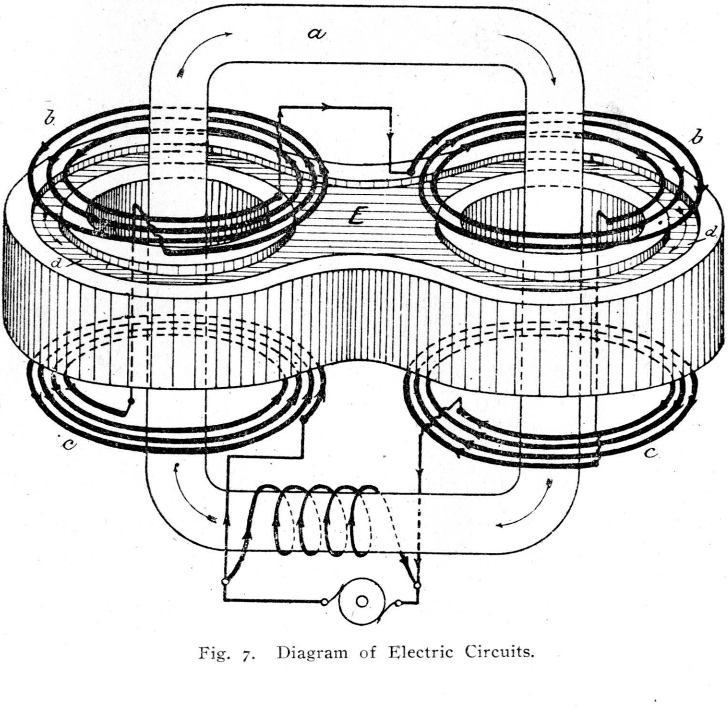

Fig. 7. Diagram of Electric Circuits.

Jessingfjord is a double-channel induction furnace, with the primary consisting of four coils connected in series. Fig. 7 shows diagrammatically the electrical principles, *E* being the steel bath, with its two channels *dd, a* the magnetic circuit, *bb* the upper coils, co-extensive with the heating channels, and *cc* the lower coils. The coils *bb* are suspended from pulleys with flexible connections, and when running, are close against the covers of the channels *dd,* but can be raised about 60 cm. (24 in.) when the covers are to be removed. The coils *bb* are un-insulated,

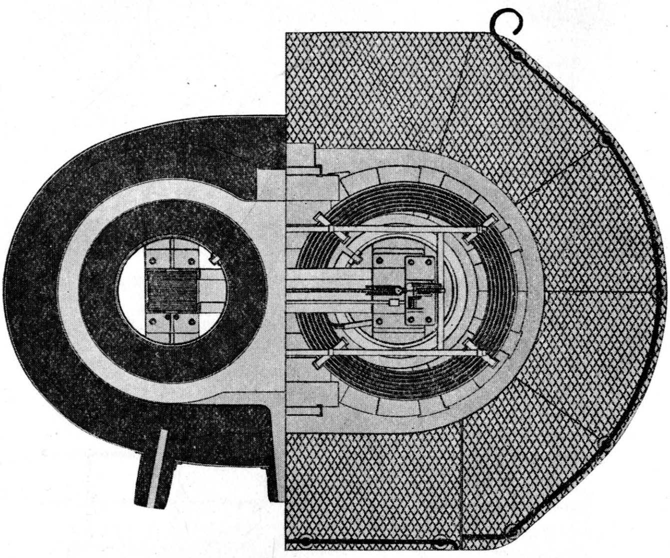

Fig. 8. Plan, half through channels and half on the platform.

bare copper bars, coiled spirally. The coils *cc* are hollow, water-cooled copper conductors, and in the actual furnace are embedded in the magnesite lining about 40 cm. (16 in.) beneath the channels *dd.* The voltage employed on the primary is so low that no particular precautions for insulation are needed, and no one can be seriously hurt by it. The space between the magnet *a* and the furnace wall is a clear 30 cm. (12 in.), which allows of the magnets (which weigh several tons) being bolted, firmly fixed, to the floor, while the furnace can be tilted for pouring. The central space *E* is 30 cm. (12 in.) wide in the middle, 60 cm.

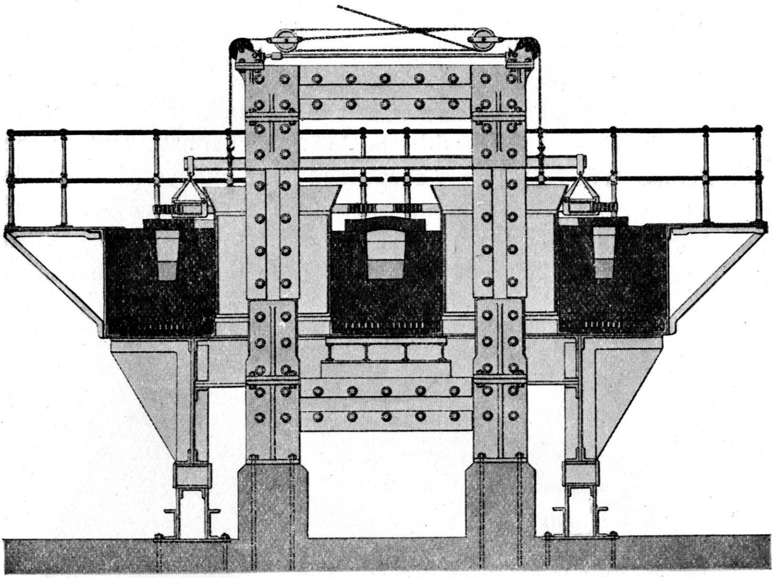

Fig. 9. Vertical Right-left Section.

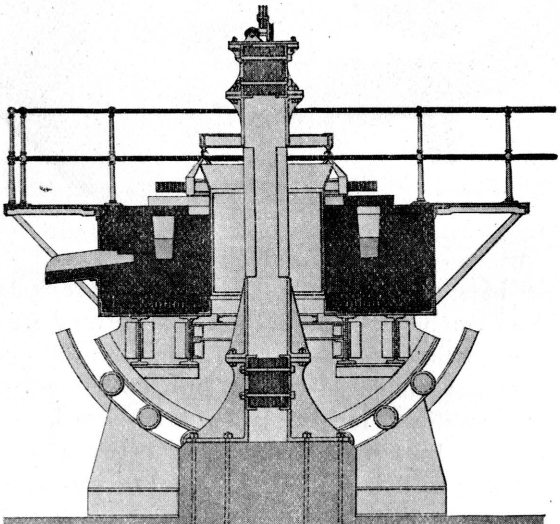

Fig. 10. Vertical Front-back Section.

(24 in.) wide at the sides, and nearly 2 meters (76 in.) long from front to back. It furnishes space enough to re-melt ingots or other scrap.

Fig. 8 shows a ground plan of the furnace; Fig. 9, a vertical section from right to left; Fig. 10, a vertical section from front to back, through one side, and Fig. 11, a vertical section from front to back, through the center, showing the furnace tilted.

On the occasion of the writer's visit, the running of the furnace was in charge of Mr. S. Cornthwaite, a Sheffield man, expert in

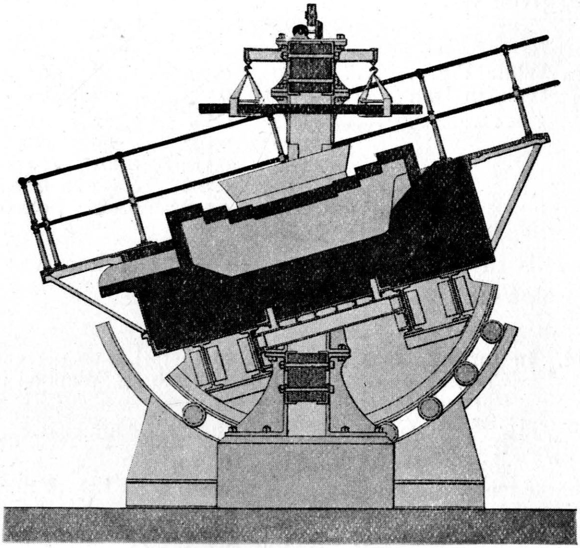

Fig. 11. Vertical Front-back Section; furnace tilted for pouring.

the manufacture and use of crucible steel. The furnace was lined with Veitsch Styrian burnt magnesite, which had been in position for seven weeks, during which it had been occasionally repaired. Norwegian magnesite had been tried and found to crumble badly; it had not been previously properly burnt. The covers were silica slabs, not sufficiently thick, however, to properly protect the melted steel from large radiation losses.

The materials being melted were the purest obtainable Swedish Dannemora pig-iron from the middle bed of the Dannemora ore deposit, and Dannemora Walloon iron, costing, respectively $30 (108 kroner) and $75 (270 kroner) per metric ton. These are the identical materials used in Sheffield for crucible melting to produce the best quality of crucible steel. Yellowish-white blast-furnace slag, vitreous and glassy, from the Dannemora furnaces, was being used as a flux, mixed with fluorspar when greater fusibility was desired. The contents of the furnace being 5 tons, 3 tons were poured at a time and 2 tons left in to start the next charge, which then consisted of 3 tons of raw materials. The analyses of the raw materials and of some steels produced from them are given as:

	C.	Si.	Mn.	S.	P.
Dannemora White Pig	3.80	0.310	1.727	0.025	0.020
" Walloon Iron	0.107	0.013	0.068	0.010	0.009
Steel	1.42	0.130	0.322	0.010	0.019
	1.20	0.107	0.269	0.009	0.019
	1.02	0.112	0.301	0.008	0.021
	0.76	0.108	0.253	0.009	0.021
	0.67	0.108	0.288	0.006	0.021

The details of the heat run off when the writer was present were as follows:

12.20 P. M. In furnace, 2,775 kg. of previous steel, 1.00 percent carbon.
Charged 1,000 kg. pig iron and 500 kg. Walloon iron.
Current started.
12.30: Current 1800 A, 273 V, 380 kw. Cos. φ 0.77.
1.30: " 1840 A, 273 V, 395 kw. " 0.80.
2.00: " 2050 A, 265 V, 380 kw. " 0.70.
2.30: Charge melted. Average current 380 kw. for 2 hrs. 10 min. = 550 kw. hours per ton of metal melted.
2.30: Charged 350 kg. pig iron and 1150 kg. Walloon iron.
3.30: Current 2275 A, 270 V, 400 kw. Cos. 0.65.
4.30: Charge melted. Average current 400 kw. for 2 hrs. = 530 kw. hours per ton of metal melted.

[Assuming 300 calories necessary to melt 1 kg. of steel, the thermal efficiency of this melting operation is 55 percent, and the furnace radiation loss calculates out 180 kw., at this temperature. It was stated by Mr. Cornthwaite that it took about 170 kw. to keep the charge melted when the furnace was kept up to heat over night.]

5.30: Current 2370 A, 265 V, 395 kw. Cos. φ 0.63.
6.00: " 2425 A, 278 V, 400 kw. " 0.59.
6.15: " 2300 A, 280 V, 365 kw. " 0.57.

Metal now at casting temperature. Current used averaged 395 kw. for 6 hours, or 790 kw. hours per ton of steel. As low as 700 kw. hours has been reached in this 5-ton furnace on cold materials.

During the heat, there was added to the bath 35 kg. of 30 percent ferro-silicon and 8.7 kg. of 80 percent ferro-manganese; while 0.15 kg. of pure aluminium (= 0.005 percent of the charge) was added in the ladle.

The steel was poured into 20 cm. square ingots of ½ ton each, and cast beautifully. These ingots are being shipped to Sheffield

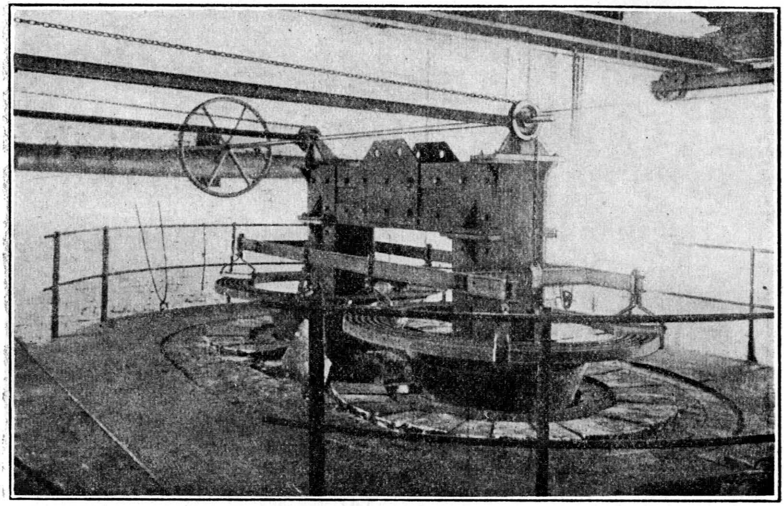

Fig. 12. Top View of Furnace.

for use in the steel works, and metal from this furnace has already given good service for razors, pocket knives, carvers, chisels, axes, files, reamers, taps, drills, turning tools (slow-speed), rock-drills, blacksmiths' tools and engineers' hammers. It sells in competition with crucible steel made from the same materials, the selling price of which is £60 ($293) per ton.

The labor required on this furnace per 24 hours was 1 head melter, 1 helper, 1 boy on each of two shifts, and 1 ladle man and 1 helper on one shift.

The capacity of the furnace is 12 tons in 24 hours, tapping a

3-ton heat every 6 hours. When in regular, steady running, 700 kw. hours are used per ton of cold charge melted.

The principle of the furnace is such that it may be increased almost indefinitely in size; a 50-ton furnace on this design is certainly practicable. In this 5-ton furnace the annular ring channels, 20 cm. (8 in.) wide by 45 cm. (18 in.) deep, are only filled 20 cm. (8 in.) deep with steel, and the narrowness increases the difficulty of working in the slag. Larger furnaces with wider channels will certainly be more free from this arching-

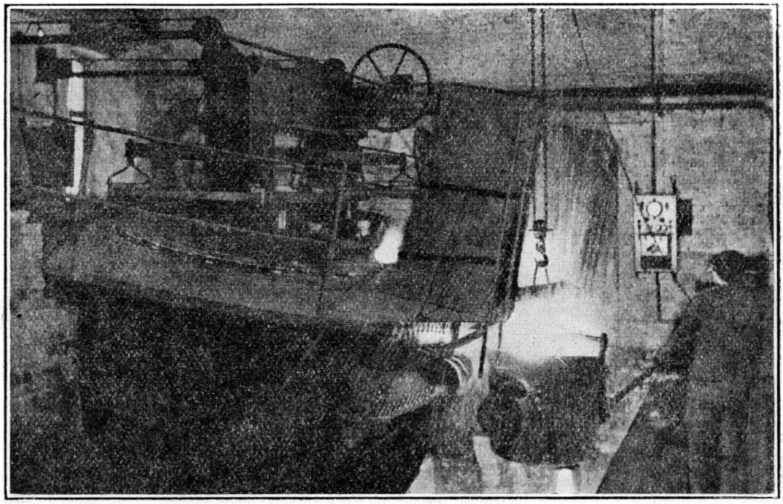

Fig. 13. Furnace in Operation; pouring a three-ton heat of crucible quality steel.

over of the slag, because it will fall of its own weight onto the metal.

It is distinctly worth while to remark that the temperature of the steel in the center compartment was fully as high as in the annular spaces, even just before the doors. This shows that, with proper heat-insulating covering over the steel, supplementary heating of the central bath is not a necessity. It appears to the writer that the difficulty heretofore met at this point is incidental merely to the smallness of the furnaces, and will disappear as larger furnaces are built. Figs. 12 and 13 show the furnace in action.

In conclusion, we may congratulate the Messrs. Hiorth and their very active staff on the high degree of success so far attained by their novel and yet very practical furnace—a furnace which has most of the advantages of the best induction furnaces without some of their serious disadvantages.

DISCUSSION.

MR. SEEDE: I would like to ask Dr. Richards what the frequency of the supply service is, and what the power service is, having two tons and five tons in the crucible.

MR. RICHARDS: The power factor of the furnace has varied around 75; it was 84, I think, on one of the test runs; the frequency was given me as 12½ cycles.

MR. CARL HERING: May I ask how it is started cold.

MR. RICHARDS: They put up originally a cupola furnace, to melt down some cast iron, in order to pour it into the furnace, and they tell me that they used it at first, but they have since abandoned its use. I cannot say just how they start it at present, unless they leave in enough metal in the bottom of the channels to form a starting ring.

MR. HERING: How about the expansion and contraction of the ring?

MR. RICHARDS: Possibly they have had difficulties with it. They said they had abandoned using the cupola, and had always left a ring of material in. The lining they had in it at the time I saw it had been running seven or eight weeks without being replaced, only requiring some patching in between the heats, so it could not have damaged the lining seriously.

MR. BENNIE: I would like to take exception to the notion that it is not possible in the ordinary type of induction furnace to charge ingots and other large pieces of metal. In a furnace that was run for sometime at Niagara Falls it would be found easily possible to do this by having a recess in the outer wall forming the crucible, putting 4-inch or 6-inch ingots upright into this recess after the bath had been formed. These ingots rapidly melted down, and owing to the rapid movement of the bath in induction furnaces we were unable to detect any local cooling due to the enlargement of the bath in the vicinity of the recess.

MR. FRARY: May I inquire how the power factor varies with the load, whether it decreases as markedly with overload as it increases with the ordinary electrode furnace.

MR. RICHARDS: I have not the details of that; it might be figured out, however, from the current readings given.

MR. LLOYD: Considering the question of the cost of power, it is always interesting to know how this is figured. One report that I saw lately on a four-million dollar investment had about $35,000 allowed for depreciation, for six months, or less than 2 percent per annum. I would like to ask Prof. Richards what allowance was made in this case for depreciation, and what percent interest was figured.

MR. RICHARDS: My remembrance was they allowed five percent depreciation per year, and figured interest at six percent.